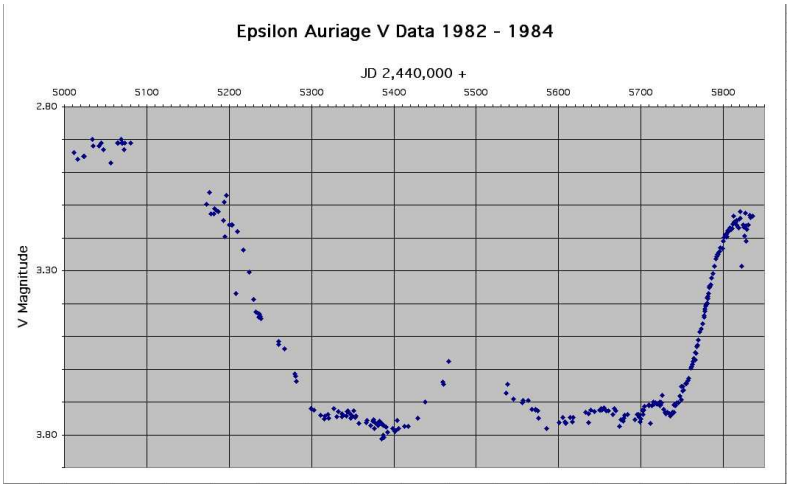
A. Epsilon Aurigae

1. The "Consensus model" for E. Aurigae has the primary star with a radius of 150 times that of the Sun but with a peak luminosity 60,000 times that of the sun. What would its surface temperature be? (10 points)

$L_{EA}=\pi R_{EA}^2\ \sigma T_{EA}^4=60000\ \pi R_s^2\ \sigma T_s^4$
$T_{EA}^4=60000^*\ T_s^4\ R_s^2/\ R_{EA}^2\ =60000/22500\ T_s^4$
So if T_s= 6000K, T_{EA} is 7667 K.

The light curve of E. Aurigae is shown below for the period 1982 to 1984.



2. What is the ratio (in absolute units) of the maximum luminosity to the minimum luminosity? (5 points)

At it's brightest, the central star is ~0.8 magnitude units brighter, a factor of $2.5^{0.8}$ or ~2 times brighter.

3. Explain why the shape of this curve is taken as evidence of an eclipsing disk. (5 points)

The light drops sharply and rises rapidly at the beginning and end of the eclipse, suggesting that the bright star is being eclipsed by a larger object. Yet there is a peak in the middle and the drop in brightness is relatively small, so this object can't be a larger star and is more likely a dim cloud surrounded by a large dust disk.

B. Milky Way Galaxy

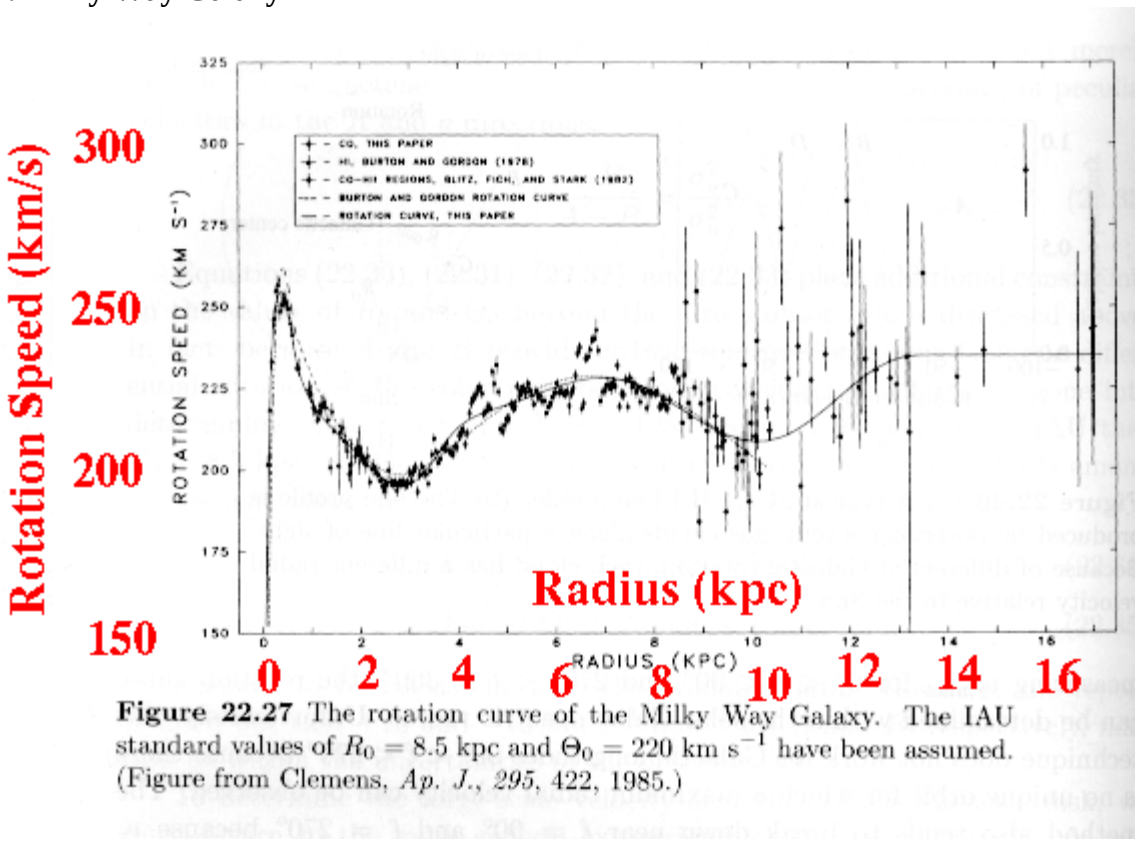


Figure 22.27 The rotation curve of the Milky Way Galaxy. The IAU standard values of $R_0 = 8.5$ kpc and $\Theta_0 = 220$ km s^{-1} have been assumed. (Figure from Clemens, *Ap. J.*, *295*, 422, 1985.)

The above is a curve of the rotation speed of the Milky Way Galaxy assuming that we are at a radius R0. It is derived largely by looking at the red shift of the 21 cm line.

4. What element is associated with this line? (2 points)

Hydrogen

5. What band (X-ray, visible, infrared, radio) is this line in, and why is it useful? (4 points)

It's in the radio band, which is capable of penetrating dust clouds and so gives a picture of things that can't be seen in the visible.

6. How much would this line shift (in wavelength) at a radius of 2 kpc? (4 points)

The speed is 200 km/s so the redshift is 200/300,000*21 cm = 42/3000 cm= 0.014 cm=0.14mm

7. Why is this curve taken as evidence of dark matter? (10 points)
Since there is much more bright material in the center of the Galaxy we would expect a curve in which velocities fell off with distance from the center. A relatively constant rotation curve implies a mass density that goes as 1/r in a disk.

C. Sgr A*

8. Sagittarius A* is a bright radio and X-ray source in Sagittarius. Why is it interesting? (5 points)

It is thought to be a massive black hole in the center of the galaxy.

9. This X-ray source brightens and dims over a period of a few months. What constraints does this put on its size? (5 points)

For an entire source to dim, it must be possible for a signal to propagate across it. This means that the source must be smaller than 2 light months or 0.05 pc.

10. The star S2 has been found to orbit SgrA* with a period of 15.24 years and an average radius of 942 AU. What is the mass of SgrA* in solar masses? (10 points)

Assuming we can use Kepler's law

$M=R^3/T^2=942^3/15.24^2=3.6 \times 10^6$ solar masses

(Note you should be able to derive this by setting the ratio of the gravitational attraction equal to the ratio of the centripetal force and assuming a circular orbit)

Peculiar Galaxies

The following are pictures of a galaxy in the optical (top) and Halpha bands (bottom).

11. What kind of galaxy is this (2 points) and what distinguishes it from other types of galaxies (3 points)?

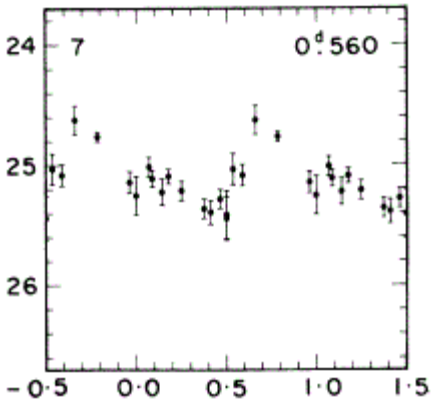
This is a starburst galaxy (M82) which is in the process of forming new stars rapidly probably as a result of strong interactions with another galaxy.

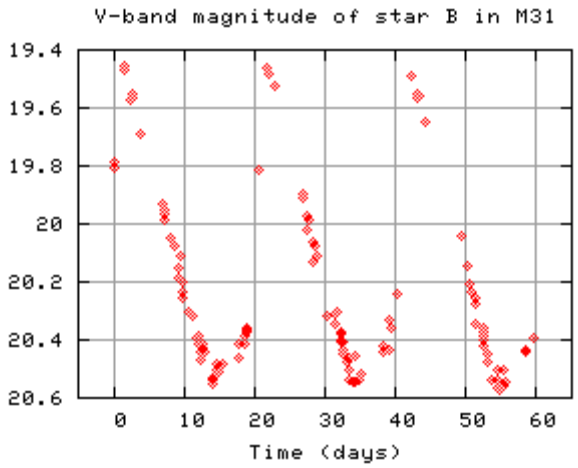
12. What does the picture in Halpha tell us about this galaxy? (5 points)

The Halpha line shows ionized hydrogen, so that the clouds above and below the galaxy result from the ejection of filaments of hot ionized gas from the galactic center.

E. M31

The plots below shows two variable stars in the Galaxy M31. The one on the left is an RR-Lyrae star, the one on the right a Cepheid variable.





13. What is the common name of the galaxy M31? (2 points)

The Andromeda Galaxy

14. Define the distance to M31 in kpc using the RR Lyrae star on the left. (8 points)

RR Lyraes have magnitudes of 0.75-0.5 (I have seen both answers on the web and so will give credit for both). Taking the higher value, a visual magnitude of around 25 means that

0.5-25=5-5 log d -> log d=29.5/5 d=794 kpc

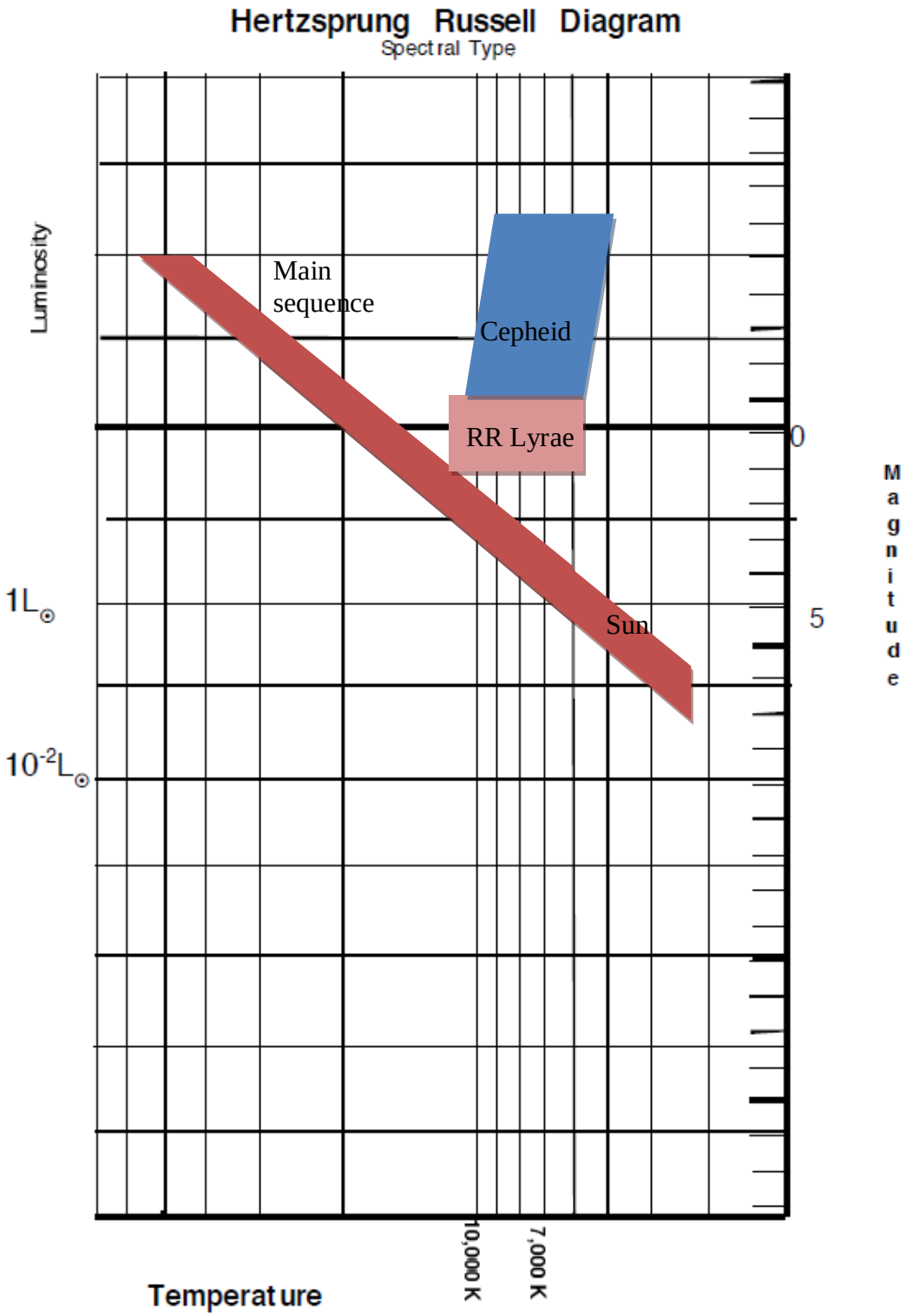
15. Define the distance to M31 in kpc using the Cepheid on the right. (8 points)

Absolute magnitude of a Cepheid is related to its period

M=-2.81 log P-1.43 so for a 20 day period the magnitude is -5. The visual magnitude is -20 so the -5-20=-25=5-log d giving d=1000 kpc

15. Place the Cepheids and RR Lyrae stars on the H-R diagram on the next page. (2 points each). Also add the Sun and the main sequence. (2 points each).

16. What causes Cepheids to vary? (4 points)
High T-> Helium ionization -> Greater opacity -> Trapping of radiation -> Increases T -> Expansion -> Cooling -> Deionization of Helium -> Less opacity -> Cooling -> Contraction (Key answer is opacity of Helium, hydrogen alone has opposite behavior)


Hertzsprung Russell Diagram
Spectral Type
Luminosity
Main sequence
Cepheid
RR Lyrae
Sun
0
5
Magnitude
1L⊙
10-2L⊙
10,000 K
7,000 K
Temperature